TECHNICAL MEMORANDUM

To:	Steve Hinton, Carlisle, MA Zoning Board of Appeals
From:	James H. Vernon, Ph.D., Nobis Engineering, Inc.
Subject:	Phase 2 Report Addendum, Independent Hydrogeologic Study, 100 Long Ridge Road, Carlisle, MA
Date:	May 20, 2015

Introduction:

Nobis Engineering, Inc. (Nobis) presents this Technical Memorandum as an Addendum to Nobis' Phase 2 report, dated May 1, 2015, on the above-referenced site. At the request of the Town of Carlisle Zoning Board of Appeals (Town), Nobis has performed additional Nitrate Loading and Mass Balance Calculations to supplement Scenarios 1 through 4, presented in the Phase 2 report (Section 2.3 and Table 4). The objective of the calculations presented here is to assist the Town with decision making regarding a proposed 40B housing development at the above-referenced site by Lifetime Green Homes (LGH). Overall project objectives are presented in the Phase 2 report.

Method and Assumptions:

The Town has requested that Nobis calculate nitrate loading and mass balance according to the method presented in "Guidelines for Title 5 Aggregation of Flows and Nitrogen Loading, 310 CMR 15.216", revised 2/11/15 (Guidelines) as closely as is feasible. The Town and Nobis recognize that in some cases this means using generalized inputs or assumptions instead of inputs or assumptions that are site-specific. The Town has further requested that Nobis conduct calculations for Areas of Impact (AOIs), to be delineated according to the Guidelines and to include "sensitive receptors", in this case drinking water wells.

The Guidelines prescribe the following assumptions and inputs:

- The mass balance analysis described in the Guidelines is applicable for certain circumstances, including estimating nitrate concentrations at sensitive receptors. "Sensitive receptors are public water supply wells, private wells, drinking water reservoirs and tributaries to drinking water reservoirs" (Guidelines, p. 6).
- The Guidelines assume that total mixing of the effluent plume and groundwater recharge due to precipitation occurs (Guidelines, p. 10).
- For a conventional septic system, wastewater effluent has a nitrate concentration of 35 milligrams per liter (mg/L), which is equivalent to 132 mg of nitrate per gallon (Guidelines, p. 12).
- With enhanced nitrate removal technologies, lower concentrations of nitrate are allowed in the calculations (Guidelines, p. 12). For example, both the LGH and Nobis have used 19 mg/L for effluent to be discharged to proposed Septic Disposal Areas 1, 2, and 3 (see

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Figure A1) in previous calculations. For the calculations presented in this Addendum, Nobis has assumed 19 mg/L for Septic Disposal Areas 1, 2, and 3. The septic system for the existing home on the site does not fall within the AOIs considered by Nobis in this Addendum.

- Wastewater volume is assumed to be 110 gallons per day (gpd) per bedroom (Guidelines, p. 5). This is the same rate used by LGH in their design (BREM_145 01.05.2015) and used by Nobis in Scenarios 1 and 3 in the Phase 2 report, Section 2.3 and Table 4. This rate was also used by Nobis in Scenarios 5 and 6, presented in this Addendum.
- On average, 1000 square feet of lawn receives 933 mg of nitrate per day in fertilizer (Guidelines, p. 12). For the present calculations, Nobis has measured the area of proposed lawn in each AOI. The areas were obtained by scanning a figure entitled "Residential Site Plan, Landscape Plan, 1 of 2" by Gardner and Gerrish, LLC in BREM_197 03.31.2015 and using Geographical Information Systems (GIS) software to determine the amount of planned lawn area in each AOI.
- Recharge to groundwater from precipitation is assumed to be 18 inches per year (5,062 liters per day (Guidelines, p. 12). (Nobis notes that both LGH and Nobis used a more site-specific recharge rate of 8.2 inches per year for mass balance calculations in the Northeast Geoscience Inc. (NGI) March 25 report and the Nobis Phase 2 report, respectively. If a site specific calculation were performed, a recharge rate of 8.2 inches per year is more likely to produce a realistic result for this site, as explained in the NGI report and in Nobis' Phase 2 Report.)
- One gallon equals 3.78 liters (Guidelines, p. 12).
- The Guidelines prescribe a 5 step process for the mass balance and nitrate loading analysis (Guidelines, p. 11 – 12).
- Step 1 describes the procedure for delineating Areas of Impact (AOIs). The delineation depends on groundwater flow directions and an assessment as to whether groundwater mounding is "significant." The flow directions and determination of whether mounding is "significant" represent the aspects of the analysis where the most discretion and hydrogeologic interpretation is involved. See below for a discussion of the particular AOIs delineated by Nobis for the calculations presented in this Addendum.
- Step 2 determines the nitrogen load by combining estimates due to wastewater discharge and fertilizer based on the assumptions described above. Background nitrate concentrations that may be present in groundwater and in rainwater are not considered. (Notes: 1. Nobis' nitrate loading calculations for Scenarios 1 – 4, presented in the Phase 2 report, Section 2.3 and Table 4, covered all or most of the site, including all portions of the site to which fertilizer might be applied. Nobis used a single, constant value for the nitrate load due to fertilizer (34,019,428 mg/yr), a value obtained from NGI's 3/25/15 report. 2. For the present calculations, Nobis uses calculated values for each AOI, assuming the Guideline's nitrate concentration of 933 mg for each 1000 square feet of lawn. See below for further details.)
- Step 3 determines the volume of recharge available by combining wastewater that is discharged with water that is recharged to groundwater from precipitation (18 inches per year as a statewide average). Other potential water inputs or outputs are not included. For the present calculations, the wastewater input is the design discharge for proposed Septic Disposal Area 1 (1,980 gpd) or for proposed Septic Disposal Areas 2 and 3, combined (3,960 gpd). The previous calculations, Scenarios 1 and 3, presented in Nobis' Phase 2 report, used a single value (5,940 gpd) for all three proposed Septic Disposal Areas, in total. (Nobis' Scenarios 2 and 4 used a Town-requested rate of 165 gpd per bedroom.)

- Step 4 provides a formula for calculating the resulting nitrate concentration for an AOI: Cn = (Lww + Lfert)/(Vww + Vr), where Cn is the concentration of nitrate; Lww is the wastewater nitrate load; Lfert is the nitrate load from fertilizer; Vww is the wastewater volume; and Vr is the volume of recharge.
- Step 5 calls for a comparison of the result to 10 mg/L, which is the regulatory threshold for nitrate in groundwater at a sensitive receptor (Guidelines, p. 6).

Nobis also notes that the Town of Carlisle has a regulatory threshold criterion of 5 mg/L of nitrate at a property boundary. The mass balance calculations presented in this Addendum are for sensitive receptors, not property boundaries.

Area of Impact Selection and Delineation:

The Town has requested that Nobis conduct nitrate mass balance calculations over separate Areas of Impact (AOIs) for proposed Septic Area 1 and for proposed Septic Areas 2 and 3, combined. The Town has requested that Nobis select sensitive receptors that are down-gradient and closest to each of these Septic Disposal Areas and delineate the AOIs for these receptors according to the methods presented in the Guidelines (p. 11 – 12).

The Guidelines, Step 1 of the mass balance procedure (p. 11), call for delineating the AOI by flow net analysis, in the downgradient direction. The upgradient edge of the AOI is defined by the upgradient edge of the SAS (soil adsorption system, in this case the proposed Septic Disposal Areas – (see Figure A1)). The Guidelines state that the "lateral extent of the AOI must be established by the groundwater divides developed beneath the SAS at design flow." An exception is called for "where groundwater mounding is not significant." In this case, "the lateral extent of the AOI will be the lateral extent of the leach bed or disposal area." This means that the AOI will be generally rectangular in cases where mounding is not significant.

The Guidelines' instructions for Step 1 require hydrogeologic interpretation and discretion in defining the downgradient and side gradient boundaries of the AOIs. Because the downgradient boundary is determined by flow net (a map of groundwater flow directions based on groundwater contours), a groundwater contour map is critical, not only for determining the orientation of the AOI, but also for determining which sensitive receptor (drinking water well) is the closest receptor in the down-gradient direction. Discretion is also called for in determining whether mounding is "significant." If the mounding is determined to be "significant", then the groundwater contour map is again critical for defining the side boundaries of the AOI.

AOI for Septic Disposal Area 1

In the Phase 2 report (page 12), Nobis concluded that the predicted mound height of 0.70 feet is not enough to alter the groundwater contouring around proposed Septic Disposal Area 1, although radial flow is possible in the immediate vicinity. Therefore, Nobis believes that in this case, mounding is not "significant", and the AOI associated with Septic Area 1 should have a width equal to the lateral extent of the disposal area. The main component of groundwater flow in this area is eastward. The nearest sensitive receptor in the eastward direction is proposed well A10.

Therefore, Nobis has delineated a generally rectangular AOI, extending from Septic Disposal Area 1 to well A10, as shown on Figures A1 and A2. The upgradient boundary of the AOI is the upgradient boundary(ies) of the proposed Septic Disposal Area (in this case the northwestern and southwestern boundaries); the side gradient boundaries are defined by the lateral extent of the Septic Disposal Area (in this case, its diagonal); and the downgradient boundary is the sensitive receptor, proposed Well A10. See Figure A2.

Nobis notes that for shallow, unconfined groundwater, the potentiometric surface (water table) usually conforms approximately to topography. Based on topography near Septic Area 1, components of groundwater flow to the south and southwest are also possible (flow arrows with question marks on Figure A1). However, flow in these directions is not proven, and sensitive receptors in these directions are farther away than well A10, so no AOI was delineated in these directions. Placement of additional monitoring well(s) to the south and/or southwest of Septic Area 1, with a new synoptic round of water level measurements would determine whether groundwater flow in these directions should be expected.

AOI for Septic Disposal Areas 2 and 3

For the purposes of analyses relative to Septic Disposal Areas 2 and 3, Nobis has simulated the combined Disposal Areas by using a composite rectangle whose area is equal to the combined areas of Septic Disposal Areas 2 and 3. (See explanation on p. 9 of the Phase 2 report.) In the Phase 2 report (p. 12), Nobis concluded that the predicted mound height of 1.53 feet for Septic Areas 2 and 3 combined is significant and may cause a noticeable change, at map scale, in groundwater contouring in the vicinity, as shown by red contour lines on Figures A1 and A3. Therefore, according to the Guidelines, the lateral boundaries of the AOI should be based on groundwater divides and not be simply a rectangle whose width is equal to the lateral extent of the Septic Disposal Area.

Identification of the downgradient receptor(s) associated with Septic Disposal Areas 2 and 3 depends on the interpretation of groundwater flow direction. Also, selecting the side gradient boundaries for the AOI(s) requires identification of groundwater divides, which are determined based on groundwater flow and contour mapping. Because the groundwater contour map is both critical and in dispute in the Septic Disposal Areas 2 and 3 vicinity, a detailed discussion of the groundwater contour mapping follows below, *in italics,* before the selected AOI is described.

> *Groundwater contour maps represent an interpretation of the groundwater potentiometric surface, which is equivalent to the water table in unconfined aquifers. These contour maps are typically constructed using a series of mapped water level measurements in wells. If a surface water body such as a brook or pond or wetland is believed to represent the water table, water levels in the surface water body can also be used for contouring groundwater. Contour maps must be made from synoptic (all water levels measured at about the same time or at least on the same day) water level measurements, which are then converted to relative or sea level elevations. For the LGH site, the contour maps are based on water level measurements collected by Northeast Geoscience (NGI) on January 23, 2015 and presented in their March 25 report. The measurements include 5 overburden well locations and 2 staff gage measurements in the brook, for a total of 7 locations with water elevation data. (For the three locations that have two wells each, Nobis averaged the water level measurements at each location.)*
>
> *NGI and Nobis both interpreted groundwater contour maps (NGI March 25 Report, Figure 3; Nobis Phase 2 Report, Figure 1) from the January 23 data set. Both maps are consistent with the 7 available data points, but the maps are very different. Critiquing the work of others is not one of Nobis' objectives; however, some discussion of the NGI contour map is presented below for comparison and explanation of Nobis' interpretation. The NGI map shows north-northeast/south-southwest contour lines that indicate east-southeast groundwater flow that appears fairly uniform throughout the site. The contour lines appear to have been drawn with consideration only for the 7 data points, and with little or no consideration for other factors.*

There are large spatial data gaps in the central portion of the site, to the south of proposed Septic Area 1, and to the north, north east, and south of Proposed Septic Areas 2 and 3. In shallow, unconfined aquifers, the water table typically is approximately parallel to the ground surface, and groundwater flow directions typically are parallel to topographic slope. It is standard hydrogeologic practice to assume that shallow groundwater flow and the water table conform approximately to topography unless there is data to indicate otherwise. Similarly, features such as streams and wetlands likely conform to the water table and likely represent groundwater discharge points (unless the stream or wetland is perched above an impermeable deposit). Nobis contoured the groundwater at the site (See Figure A1) based on three factors:

1. *NGI's water level measurements on 1/23/15;*
2. *Site topography and streams; and*
3. *Predicted groundwater mounding at proposed Septic Disposal Areas 2 and 3.*

In Nobis' opinion, the groundwater contour map presented in Figure A1 is more likely to represent the water table and groundwater flow directions at the site than a map that has straight groundwater contours based only on the monitoring well measurements. Nobis also recognizes that neither map can be proven correct in locations away from the monitoring wells and staff gauges. The best way to resolve questions regarding the water table and groundwater flow directions is to install additional monitoring wells in key locations and to conduct a new synoptic water level measurement round.

Also, in the vicinity of proposed Septic Disposal Areas 2 and 3, the terrain has already been altered to make a level area for horseback riding. In the western part of the riding area, several feet of soil have been removed in the vicinity of proposed Septic Disposal Area 3. In the eastern part of the riding area, east of proposed Septic Disposal Area 2, fill has been emplaced, apparently several feet thick at the eastern edge. The effects, if any, on the local water table are unknown. Finally, at least one drain pipe conducts water away from the toe of the fill area. Artificial features such as this could have a significant effect on local groundwater flow, the water table, and future nitrate transport. None of these factors are accounted for in Nobis' groundwater contour maps or mass balance analyses.

Where mounding is "significant", the Guidelines call for the side-gradient boundaries of the AOI to be delineated to groundwater divides developed at design flow (mounding included). This means that the groundwater contour and flow map must be used to locate local groundwater divides. Topographic and groundwater contours indicate that a local groundwater divide is probably present just west of proposed Septic Disposal Area 3 and roughly along the site's western property line. (See black groundwater divide "a" on Figures A1 and A3.) Based on present data, the location of the line can only be determined approximately, and it is unknown if the groundwater divide is high enough to prevent mounded wastewater from flowing past this divide to the southwest. Also, the mounding itself will create a groundwater divide in the immediate vicinity of proposed Septic Disposal Areas 2 and 3. (See black groundwater divide "b" on Figures A1 and A3.) This divide is conceptual and could only be mapped accurately with additional data and a numerical groundwater flow model. Divide "b" cannot be mapped away from the Septic Disposal Areas with present information.

For proposed Septic Disposal Areas 2 and 3, the primary groundwater flow direction is probably to the northeast. Components of flow also exist to the east and east-southeast. Possibly,

southerly and even southwesterly flow also occurs, although an interpreted groundwater flow divide ("a" on Figures A1 and A3) may prevent groundwater from flowing far in these directions. The nearest sensitive receptor in the northeasterly downgradient direction is the existing well at 55 Suffolk Lane Extension. However, proposed Well A4 is much closer and is obliquely down-gradient, to the east-southeast. Therefore, AOI-2/3 is delineated with well A4 as the downgradient boundary. The downgradient boundary is arcuate, at the same distance from the composite Septic Disposal Area as well A4. The arcuate downgradient boundary extends in both directions (see below). The upgradient boundary is the upgradient (northwestern) edge of the combined Septic Disposal Areas 2 and 3. Delineating the side-gradient boundaries is more problematic. The local groundwater divide developed as a result of mounding ("b" on Figure A3) cannot be mapped far enough to the south to extend to the downgradient AOI-2/3 boundary. Therefore, Nobis used groundwater divide "a", to the west of the Septic Disposal Areas as the southerly side-gradient boundary. Delineating the northern side gradient boundary is more problematic. (As one proceeds northward from Septic Disposal Area 3, at some location, flow lines will no longer originate from the Disposal Area. However, the data for determining that location is not available. Therefore, the northern side-gradient boundary is extended all the way to a point where the arcuate downgradient boundary meets an extension of the upgradient boundary.) AOI-2/3 and its boundaries are shown on Figure A3.

Because of the uncertainties described above, especially with the northern side-gradient boundaries, the delineated AOI is probably more generous than necessary, resulting in additional recharge in the northern, wooded area. If information were available that allowed a closer side-gradient boundary, there would probably be less dilution and a greater resulting nitrate concentration.

Results:

AOI for Septic Disposal Area 1

The AOI for Septic Disposal Area 1 (AOI-1) has a total area of 16,669 square feet, of which 4,190 square feet is impervious (proposed home #2 plus road and driveway). The impervious area is discounted from the recharge total according to the Guidelines. As described above, fertilizer is assumed to be applied to future lawns ("loam and seed areas" shown on Landscaping Figure 1 of 2 in BREM_197 03.31.2015). These areas account for 4,806 square feet east of the road and 1,849 square feet west of the road and were used to calculate the nitrate load due to fertilizer, as described above. When the inputs are applied to the formula in Step 4 of the Guidelines, the resulting nitrate load for a year is 54,170,641 mg; the total volume of water is 3,261,060 L; the resulting predicted nitrate concentration is 16.6 mg/L (Scenario 5 in Table A1).

If an alternate AOI were delineated southeastward to proposed well A11, the results would probably be similar. Well A11 is a similar distance from Septic Disposal Area 1; proposed home #1 and associated road and driveway areas probably have similar areas; and lawn areas appear roughly similar.

The existing well that serves the home at 90 Long Ridge Road is also downgradient of Septic Disposal Area 1, but farther away than Well A10 and A11. Nobis did not delineate an AOI extending to this well or perform a nitrate mass balance calculation. There has not been enough time to determine the areas of lawn and impervious surface that would be needed to perform a nitrate mass balance analysis for an AOI extending to the well at 90 Long Ridge Road. Therefore, at present there is not enough information to conclude that a result at 90 Long Ridge Road would be less than 10 mg/L or 5 mg/L for nitrate.

Existing wells that serve homes at 200 Long Ridge Road and 68 Garnet Rock Lane are located southwest and south of proposed Septic Disposal Area 1 respectively. If groundwater flow components in these directions are verified, Nobis recommends that AOIs be delineated and nitrate concentrations estimated for these locations, using the Guidelines or site-specific parameters.

It must be remembered that all calculations presented here are for the overburden and assume that all wastewater that is discharged fully mixes with groundwater in the AOI. The results for AOI-1 at proposed well A10 are for the overburden at that location and are not predictions of nitrate concentrations in bedrock in a well to be drilled at the location.

AOI for Septic Disposal Areas 2 and 3

The AOI for proposed Septic Disposal Areas 2 and 3 combined (AOI-2/3) is 114,707 square feet, of which 20,205 square feet is impervious (proposed homes 8, 9, 10, 11, and 18 plus driveways and road). The impervious area is discounted from the recharge total according to the Guidelines. As described above, fertilizer is assumed to be applied to future lawns ("loam and seed areas" shown on Landscaping Figure 1 of 2 in BREM_197 03.31.2015); these areas account for a total of 24,698 square feet and were used to calculate the nitrate load due to fertilizer, as described above. When the inputs are applied to the formula in Step 4 of the Guidelines, the resulting nitrate load for a year is 1.12xE8 mg; the total volume of water is 9,471,593 L; the resulting predicted nitrate concentration is 11.8 mg/L (Scenario 6 in Table A1). If information were available to delineate the northern side-gradient boundary more closely, the area available for recharge would be smaller and probably would result in a higher predicted concentration at the well A4 location.

If AOI-2/3 were expanded to include proposed well A8, located southeast of proposed Septic Disposal Areas 2 and 3, the calculated nitrate concentration would probably be similar to that for well A4. However, there would be less confidence in the result because well A8 is more obliquely downgradient of the Septic Disposal Areas than well A4.

The existing well that serves the home at 55 Suffolk Lane Extension is more directly downgradient than either A4 or A8, but is much farther away, with little impervious or fertilized area intervening. Nobis did not delineate an AOI nor perform a mass balance calculation for this existing well, but expects the result to be significantly lower than for A4.

Nobis did not delineate AOIs or perform mass balance calculations at property lines, but AOI-2/3 extends well beyond the LGH property line northeast of proposed Septic Areas 2 and 3. If a mass balance calculation were performed for an AOI that terminated at this boundary, it is reasonable to assume that the result would be greater than the 10 mg/L regulatory threshold, the 5 mg/L Town criterion, or the 11.8 mg/L result discussed above.

Proposed well A3 and the existing well that serves the home at 132 Long Ridge Road are both closer to proposed Septic Disposal Areas 2 and 3 than any of the wells discussed above, but are located south of the Septic Disposal Areas (Figure A3). There is not enough data to indicate that groundwater from the Septic Disposal Areas flows toward these wells; an interpreted groundwater divide that intervenes between the wells and the wells may or may not be accurately mapped and high enough to prevent groundwater from the septic disposal areas to reach these wells. Nobis recommends that one or more new monitoring wells or piezometers should be installed to determine groundwater conditions in this area.

It must be remembered that all calculations presented here are for the overburden and assume that all wastewater that is discharged fully mixes with groundwater in the AOI. The results for

AOI-2/3 at proposed well A4 are for the overburden at that location and are not predictions of nitrate concentrations in bedrock in a well to be drilled at the location.

Conclusions and Recommendations:

Nobis has performed nitrate mass balance estimates at Areas of Impact (AOIs) associated with proposed Septic Disposal Area 1 and with proposed Septic Disposal Areas 2 and 3 combined. Nobis was asked by the Town of Carlisle to perform the calculations following the Mass DEP's "Guidelines for Title 5 Aggregation of Flows and Nitrogen Loading, 310 CMR 15.216" as closely as feasible, even when this means applying generalized instead of site-specific assumptions, most especially the annual recharge rate (18 inches per year).

Nonetheless, the calculations are highly site specific in that selection of the nearest downgradient receptor (drinking water well) and the delineation of the AOI boundaries are highly dependent on groundwater contour and flow maps for the site. Nobis recognizes that the present available data set allows more than one interpretation for groundwater contours and flow direction, but believes that the map presented here and in the Phase 2 report, which shows primary flow to the northeast from proposed Septic Disposal Areas 2 and 3, is the most reasonable interpretation of the available data. If controversy remains or if assessments of possible impacts to the northeast and south of Areas 2 and 3 and to the southwest and south of Area 1 are needed, new monitoring wells should be installed, and a new synoptic round of water level measurements should be conducted.

The calculations described in this Phase 2 report Addendum indicate that concentrations of 16.6 mg/L and 11.8 mg/L, respectively, are the results for AOIs delineated from proposed Septic Disposal Area 1 and Areas 2 and 3 combined, to the nearest downgradient sensitive receptors (Wells A10 and A4, respectively) for groundwater in the overburden. The Guidelines do not provide a method for assessing nitrate concentrations in bedrock. Nobis discounted impervious area from the calculations, based on the applicant's plans; Nobis assumed that fertilizer would be applied to lawn areas labeled as "loam and seed" on LGH's plan.

Both calculated nitrate results are greater than the regulatory threshold concentration of 10 mg/L.

Tables

Figures

TABLE AI

MASS-BALANCE NITRATE LOADING ANALYSES - ADDITIONAL SCENARIOS

100 Long Ridge Road
Carlisle, Massachusetts

Scenario 5 — **AOI-1**

Wastewater Yearly Volume Area 1 (L/yr)	=	W_{A1}	=	2,731,806
Nitrate Load from Fertilizer (mg/yr)	=	N_F	=	2,266,327
Recharge from Precipitation (ft/yr)	=	R_P	=	1.5
Area (ft^2)		A_S	=	12,479
Wastewater Nitrate Concentration Area 1 (mg/L)	=	N_{A1}	=	19

	$(W_{A1} \times N_{A1})$	+	N_F			=	Load		
Load	51,904,314		2,266,327			=	54,170,641	mg	
	W_{A1}	+	$(R_P \times A_S$	x	7.48 gal / ft^3 x 3.78 L / gal)	=	Volume		= **16.6 mg/L Scenario 5**
Volume	2,731,806		18,719	x	28.27	=	3,261,060	L	

Scenario 6 — **AOI-2/3**

Wastewater Yearly Volume Area 1 (L/yr)	=	$W_{A2/3}$	=	5,463,612
Nitrate Load from Fertilizer (mg/yr)	=	N_F	=	8,410,780
Recharge from Precipitation (ft/yr)	=	R_P	=	1.5
Area (ft^2)		A_S	=	94,502
Wastewater Nitrate Concentration Area 1 (mg/L)	=	$N_{A2/3}$	=	19

	$(W_{A2/3} \times N_{A2/3})$	+	N_F			=	Load		
Load	103,808,628		8,410,780			=	112,219,408	mg	
	$W_{A2/3}$	+	$(R_P \times A_S$	x	7.48 gal / ft^3 x 3.78 L / gal)	=	Volume		= **11.8 mg/L Scenario 6**
Volume	5,463,612		141,753	x	28.27	=	9,471,593	L	

Notes:
1. These analyses follow the methods and assumptions of "Guidelines for Title 5 Aggregation of Flows and Nitrogen Loading, 310 CMR 15.216."
2. The analyses apply to Areas of Impact, delineated according to the Guidelines and explained in the text of Nobis' Addendum 2 to the Phase 2 Report.
3. Maps and explanations for Scenarios 5 & 6 are found in the text of the Addendum. (Scenarios 1 - 4 were presented on Table 4 of the Phase 2 Report.)

Proposed Septic Disposal Area 3

Proposed Septic Disposal Area 2

AOI-2/3

Suffolk Lane Extension

#55

MW-2A
MW-2
113.92

MW-3A
MW-3
109.46

113.21

MW-4
91.66

A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11

MW-5
91.72

SG-2
90

#132

#100

MW-1A
MW-1
103.01

Outcrop 1

Proposed Septic Disposal Area 1

103.71

SG-1
87

#200

#90

AOI-1

Garnet Rock Lane

Long Ridge Road

Suffolk Lane

#68

110
105
100
95
90
70
60
58

Notes:

1. Proposed well and septic locations from Brem_127_12.08.2014.
2. Monitoring Well Locations are from NGI report dated 3/25/15
3. Assessor's parcels are from the Town of Carlisle. Aerial photography provided by ESRI. Lot line for #90 Long Ridge Road is Approximate. Topographic contours are from Mass GIS.
4. Elevations are to a relative datum, not sea level.
5. Water elevations are from NGI report dated 3/25/15. Masurements taken 1/23/15.
6. Where 2 adjacent monitoring wells are present, Nobis averaged the water level elevatios in NGI 3/25/15 report, Table 1.
7. Locations of site features depicted hereon are approximate and given for illustrative purposes only.
8. See text for further explanation.

0 75 150 300

Feet

1 inch = 150 feet

Legend

- A1 — Proposed Well with LGH # (Location Approximate)
- Groundwater Flow Estimate (With Mounding) (Dashed Where Inferred From Topography)
- Other Supply Well
- MW-2 113.92 — Monitoring Well with Water Elevation (to Relative Datum on 1/23/15)
- 113.21 — Predicted Mound Height
- SG-2 90 — Staff Gauge Installed by NGI with Water Elevation (to Relative Datum on 1/23/15)
- Proposed Septic Disposal Area
- Composite Conceptual Septic Disposal Area
- LGH Project Site
- Area of Impact (See text for explanation)
- 10 Foot Topographic Contour
- 1 Foot Topographic Contour
- Groundwater Divide (see text for explanation)
- Bedrock Outcrops
- 5 Foot Overburden Groundwater Level Contour (Dashed Where Inferred; see text for explanation)
- Predicted Overburden Groundwater Level Contour with Mounding (see text for explanation)

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FIGURE A1

OVERBURDEN GROUNDWATER POTENTIOMETRIC SURFACE MAP
WITH AREAS OF IMPACT
100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 89220.00	DATE: MAY 2015

Path: J:\89220.00 - Carlisle Hydrogeo Evaluation 2015\GIS\Figures\Fig_A1_Carlisle_AOI_Overview.mxd Date Printed: 5/20/2015

Septic Area = 2,912

Proposed Septic Disposal Area 1

Fertilized Areas = 6,654

Non Fertilized Area = 1,181

Impervious Areas = 4,190

AOI-1

#200

#68

#90

Garnet Rock Lane

Long Ridge Road

LONG RIDGE ROAD (40' PUBLIC RIGHT OF WAY)

PRIVATE ROAD

MW-1A

MW-1
103.01

103.71

A1

A7

A10

A11

SG-1
87

105

100

95

90

Notes:

1. Proposed well and septic locations from Brem_127_12.08.2014.

2. Monitoring Well Locations are from NGI report dated 3/25/15

3. Assessor's parcels are from the Town of Carlisle. Aerial photography provided by ESRI. Lot line for #90 Long Ridge Road is Approximate. Topographic contours are from Mass GIS.

4. Elevations are to a relative datum, not sea level.

5. Water elevations are from NGI report dated 3/25/15. Masurements taken 1/23/15.

6. Where 2 adjacent monitoring wells are present, Nobis averaged the water level elevatios in NGI 3/25/15 report, Table 1.

7. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

8. See text for further explanation.

9. Areas shown in square feet.

10. Scanned basemap in Landscape Plate 1 of 2 from Brem_197_03.31.2015.

0 25 50 100

Feet

1 inch = 50 feet

Legend

- A1 — Proposed Well with LGH # (Location Approximate)
- Groundwater Flow Estimate (With Mounding) (Dashed Where Inferred From Topography)
- Other Supply Well
- MW-2 103.01 — Monitoring Well with Water Elevation (to Relative Datum on 1/23/15)
- 103.71 — Predicted Mound Height
- SG-1 87 — Staff Gauge Installed by NGI with Water Elevation (to Relative Datum on 1/23/15)
- Proposed Septic Disposal Area
- LGH Project Site
- Area of Impact
- Bedrock Outcrops

AOI Surface Type

- Areas Typically Fertilized
- Area Typically Not Fertilized
- Impervious Areas

- 5 Foot Overburden Groundwater Level Contour (Dashed Where Inferred; see text for explanation)

N

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FIGURE A2

OVERBURDEN GROUNDWATER POTENTIOMETRIC SURFACE MAP WITH AREA OF IMPACT - 1
100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 89220.00	DATE: MAY 2015

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Non Fertilized Areas = 64,238

Impervious Areas = 20,204

Fertilized Areas = 24,698

Upgradient Boundary

Downgradient Boundary

Southern Side Gradient Boundary

Proposed Septic Disposal Area 3

Proposed Septic Disposal Area 2

AOI-2/3

Suffolk Lane Extension

#55

#132

a

b

MW-2A
MW-2
113.92
113.21

MW-3A
MW-3
109.46

MW-4
91.66

MW-5
91.72

SG-2
90

A1

A3

A4

A5

A6

A8

A9

Notes:

1. Proposed well and septic locations from Brem_127_12.08.2014.
2. Monitoring Well Locations are from NGI report dated 3/25/15
3. Assessor's parcels are from the Town of Carlisle. Aerial photography provided by ESRI. Lot line for #90 Long Ridge Road is Approximate. Topographic contours are from Mass GIS.
4. Elevations are to a relative datum, not sea level.
5. Water elevations are from NGI report dated 3/25/15. Masurements taken 1/23/15.
6. Where 2 adjacent monitoring wells are present, Nobis averaged the water level elevatios in NGI 3/25/15 report, Table 1.
7. Locations of site features depicted hereon are approximate and given for illustrative purposes only.
8. See text for further explanation.
9. Areas shown in square feet.
10. Scanned basemap in Landscape Plate 1 of 2 from Brem_197_03.31.2015.

0 35 70 140

Feet

1 inch = 70 feet

Legend

- A1 — Proposed Well with LGH # (Location Approximate)
- Groundwater Flow Estimate (With Mounding) (Dashed Where Inferred From Topography)
- Other Supply Well
- MW-2 113.92 — Monitoring Well with Water Elevation (to Relative Datum on 1/23/15)
- 113.21 — Predicted Mound Height
- SG-2 90 — Staff Gauge Installed by NGI with Water Elevation (to Relative Datum on 1/23/15)
- Proposed Septic Disposal Area
- Composite Conceptual Septic Disposal Area
- LGH Project Site
- Groundwater Divide (see text for explanation)
- Area of Impact
- 5 Foot Overburden Groundwater Level Contour (Dashed Where Inferred; see text for explanation)
- Predicted Overburden Groundwater Level Contour with Mounding (see text for explanation)

AOI Surface Type

- Areas Typically Fertilized
- Area Typically Not Fertilized
- Impervious Areas

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FIGURE A3

OVERBURDEN GROUNDWATER POTENTIOMETRIC SURFACE MAP WITH AREA OF IMPACT 2/3
100 LONG RIDGE ROAD
CARLISLE, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JV
PROJECT NO. 89220.00	DATE: MAY 2015

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